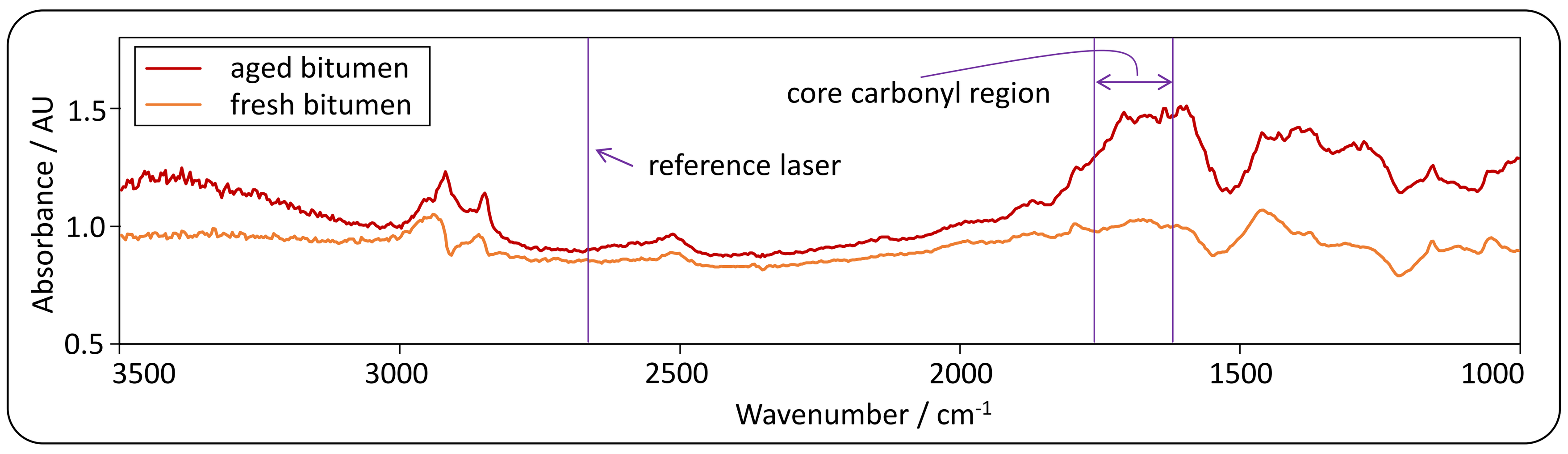
Standoff measurement of spectral changes in UV-aged bitumen

NM Davis[a], J Hodgkinson[a], S Staines[a], C Browne[b], K Nesnas[b], A Wright[b], S McRobbie[b,c] and RP Tatam[a]

a) Engineering Photonics, Cranfield University, UK b) TRL, Wokingham, UK c) Now at National Highways, Guildford, UK

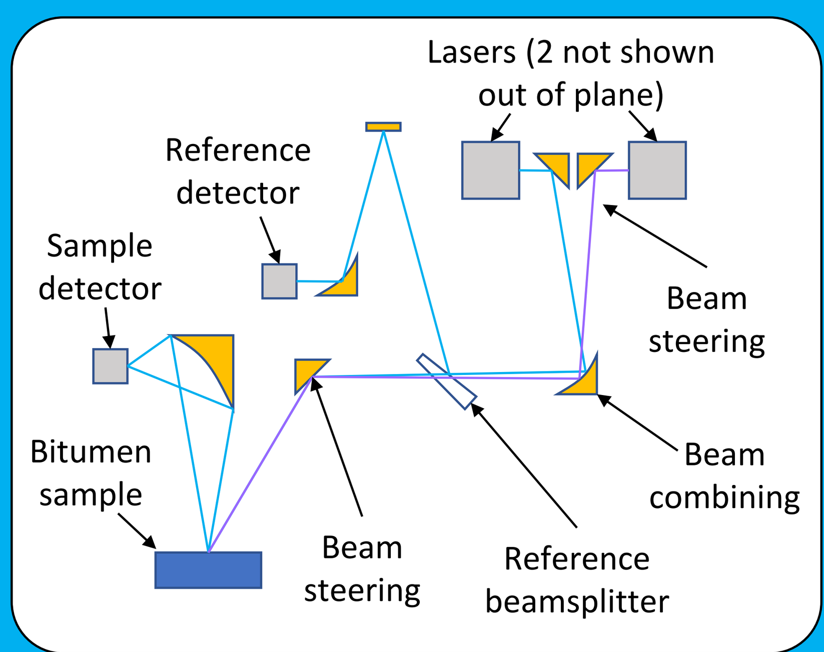
Introduction

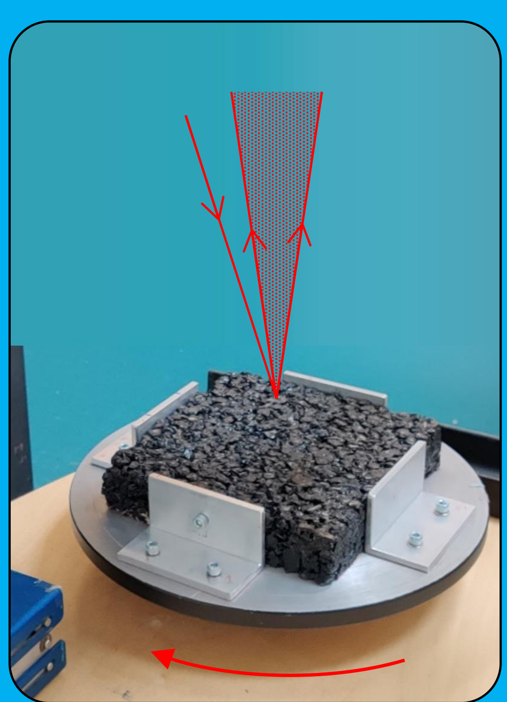
- UV-induced oxidation is considered the primary chemical degradation mechanism of bitumen in asphalt, increasing the number of carbonyl bonds in the material [1].
- Previously, a hand-portable FTIR spectrometer was used to measure changes in diffusely reflected spectral features associated with carbonyl and other bonds in artificially aged bitumen and on closed roads [2]. This is slow (can take several minutes per measurement) and requires physical contact with the sample which can damage the optics.
- Changes in the spectrum at the wavelengths associated with carbonyl features can be associated with UV-induced ageing of the bitumen [2], as can be seen in the graph below.
- We have developed a new instrument for standoff measurements of surface reflectivity. The aim is to quantify the level of oxidation of bitumen, and thereby develop techniques to predict the onset of deterioration of road pavements.



Principle of Operation

- 3 Quantum Cascade Lasers (QCL) used at wavelengths corresponding to carbonyl region and one interband Cascade Laser (ICL) at a reference wavelength.
- Lasers modulated sinusoidally between 20 and 40 kHz. Output was combined and directed towards the target sample at 15° normal to the surface.



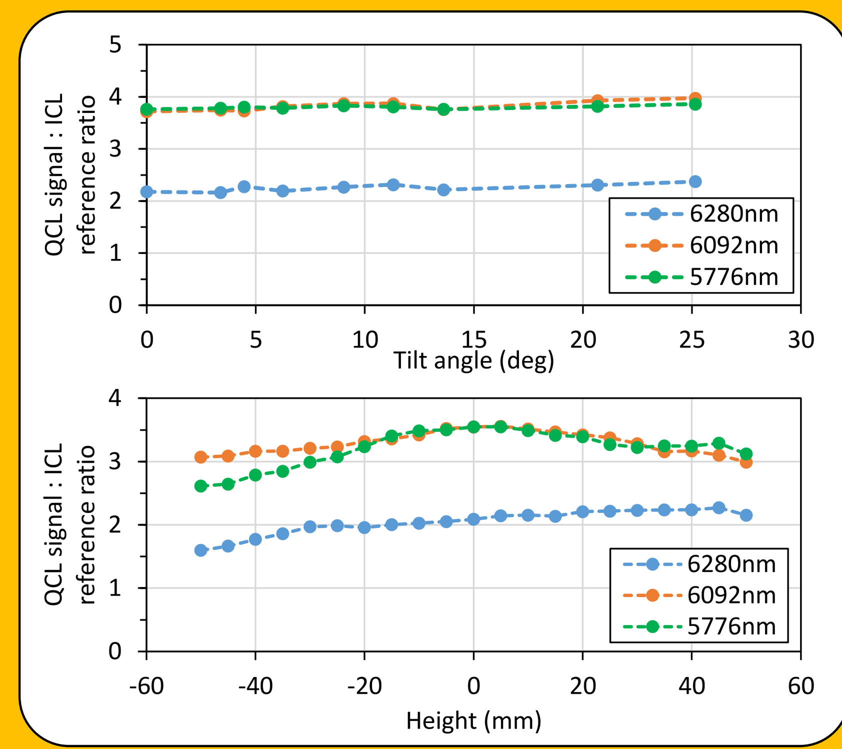


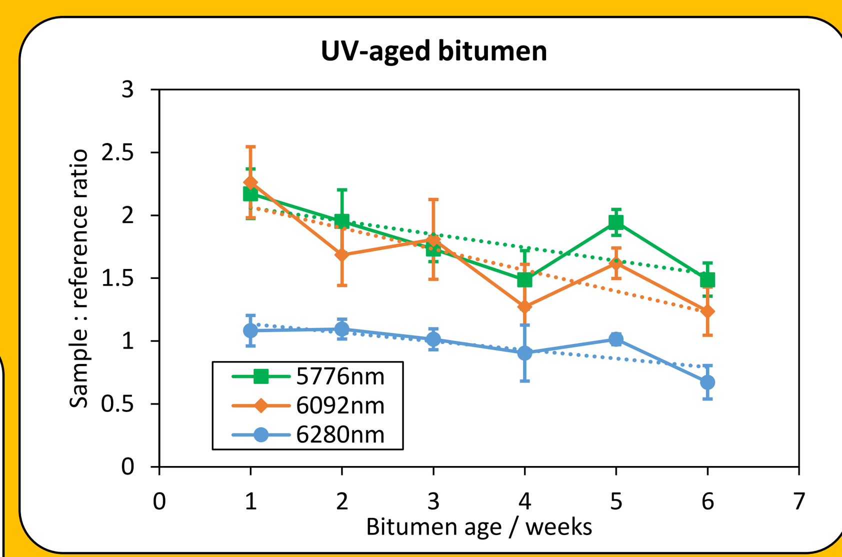
- Reflected light collected by a single detector, with the 4 signals demodulated using lock-in amplifiers.
- Reference arm used to correct for fluctuations in laser intensity and changes in atmospheric water vapour.

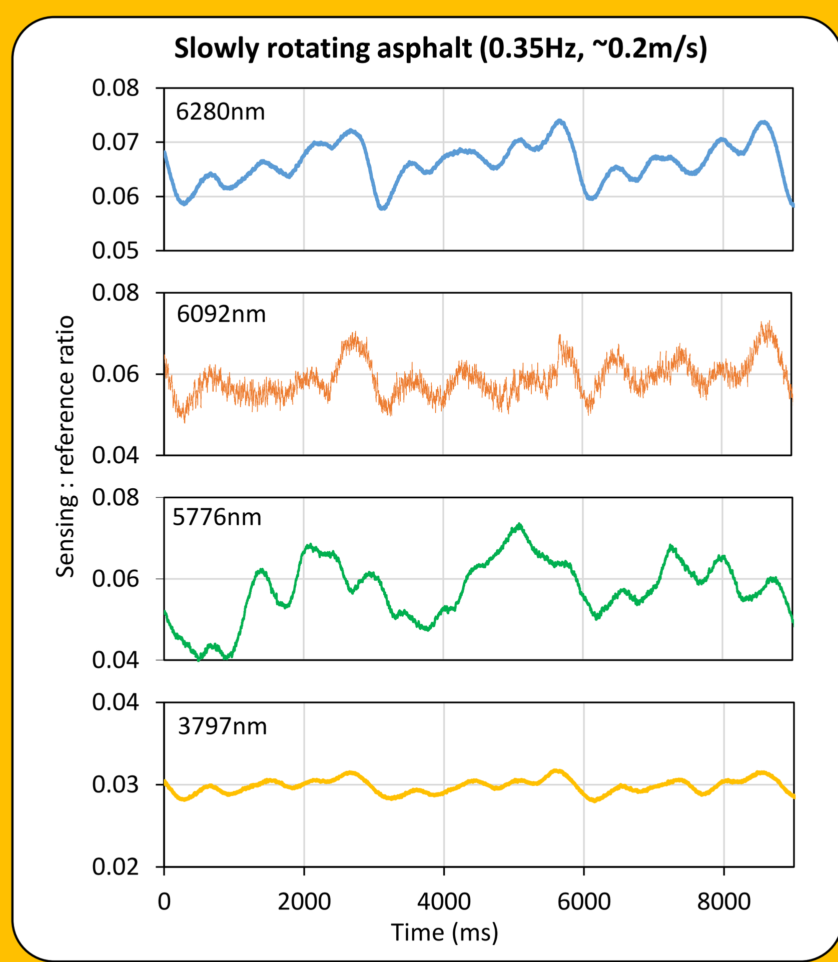
- Principle tested in the lab (see above photo), then Instrument mounted on a trolley for outdoor testing, with battery power and a touchscreen mounted on the trolley handle for user control.

Laboratory Results

- Measurements of the instrument's sensitivity to changes in height and tilt were made.
- A tolerance of ±2cm can be observed for changes in height, with the instrument shown to be able to withstand changes in the surface angle to at least 25 degrees.
- Samples of artificially UV-aged Bitumen (1-6 weeks) were measured at 6 defined locations on each sample (~5cm apart) and averaged. The trend seen in the data is consistent with a reduction in reflectivity in the carbonyl region.



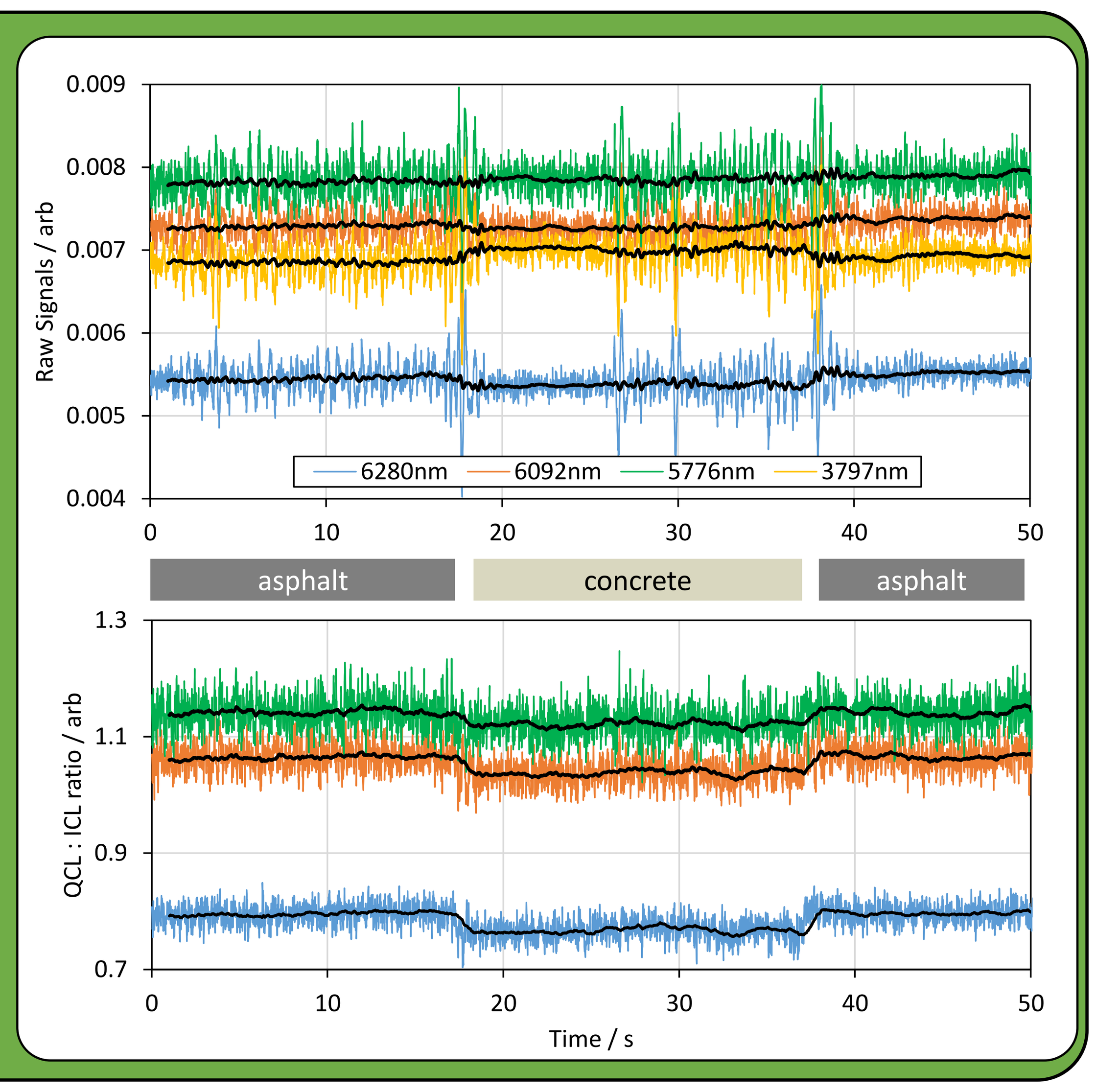




- Measurements of rotating asphalt (simulating road movement at low speed) were undertaken.
- 3 rotations of the platform can be seen in each plot. Undulations in the measured diffusely reflected light for each laser is partly a result of the signal reflecting differently as different angles of surface move into and out of the beam, but also due to the beam moving between the bitumen and aggregate.

Outdoor Tests

- Output monitored whilst trolley pushed over transitions between different patches of asphalt and concrete.
- Clear dip in signal strength can be observed as trolley moves from asphalt to concrete.
- Spikes seen in unreferenced laser data cancel out when referenced to the ICL.



Conclusions

- Instrumentation developed to measure spectroscopic changes in UV-aged bitumen.
- A clear trend has been observed between 1-6 week aged samples.
- Measurements on rotating asphalt indicate that variations in the surface can be observed.
- Instrument was mounted onto a trolley with preliminary outdoor tests undertaken.
- Initial findings indicate that the instrument can detect changes in the surface material.

References

[1] M. R. Nivitha, E. Prasad, and J. M. Krishnan, "Ageing in modified bitumen using FTIR spectroscopy," International Journal of Pavement Engineering, vol. 17, no. 7, pp. 565–577, 2016.

[2] H. Bowden, M. J. Almond, W. Hayes, C. Browne, and S. McRobbie, "The use of diffuse reflectance infrared spectroscopy to monitor the oxidation of UV irradiated and naturally aged bitumen and asphalt," Road Material and Pavement Design, vol. 22, no. 6, pp. 1254-1267, 2019.

NM Davis n.m.davis@cranfield.ac.uk
J Hodgkinson j.hodgkinson@cranfield.ac.uk

Engineering Photonics, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK

Funded by